

Open charm measurement in p+p $\sqrt{s} = 200$ GeV collisions at STAR

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Abstract

The charm production is sensitive to early dynamics of the created system in RHIC heavy ion collisions. Dominant process of charm quarks production at RHIC is believed to be initial gluon fusion which can be calculated in the perturbative QCD. Understanding both the charm production total cross section and the fragmentation in p+p collisions is a baseline to further exploring the QCD medium via open charm and charmonium in heavy ion collisions. In this paper we present the first reconstruction of open charm meson D^0 via the weak decay to K and π mesons in the p+p collisions at $\sqrt{s} = 200$ GeV. The analysis is based on the large p+p minimum bias sample collected in RHIC year 2009 by the STAR detector. The D^0 decay daughter identification was improved by using the data of the newly installed Time-Of-Flight detector with 72% of its designed coverage.

Key words: charm hadrons, proton-proton collisions

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1. Introduction

The charm quark production is dominated by initial gluon fusion at initial hard partonic collisions during heavy ion collisions. This production can be described by perturbative QCD (pQCD) due to the large mass (~ 1.5 GeV/ c^2) of the charm quark [1]. Its mass is given by Electroweak spontaneous symmetry breaking and the QCD chiral symmetry breaking does not affect charm quark mass [2]. Unlike light quarks (u,d,s), charm quarks cannot be easily produced during the mixed and hadronic phases of the dense matter since the charm mass is much larger than the corresponding temperature scale [3] at RHIC collision energies. In gluon radiative energy loss mechanism, charm quarks suffer less energy loss while traversing through the dense partonic matter due to Dead Cone Effect [4]. All these phenomena make charm quark an excellent probe of the Quark Gluon Plasma. Open charm analysis in p+p collisions is a crucial baseline to further explore the QCD medium via open charm and charmonium in heavy ion collisions.

2. The Measurement

Identification of charmed hadrons is difficult due to their short lifetime ($c\tau(D^0) = 123 \mu\text{m}$), low production rates, and large combinatorial background. The open charm yield $dN_{D^0}^{pp}/dy$ is calculated from D^0 meson invariant mass reconstruction directly through the hadronic decay channel $D^0(\bar{D}^0) \xrightarrow{\Gamma_i/\Gamma=0.038} K^\mp \pi^\pm$ and from D^* through the invariant mass difference between D^* and D^0 taken from $D^{*\pm} \xrightarrow{\Gamma_i/\Gamma=0.677} D^0(\bar{D}^0)\pi^\pm$ decay. In what follows, we imply $(D^0 + \bar{D}^0)/2$ when using the term D^0 unless otherwise specified. The data used in this analysis were taken during the 2009 RHIC run in p+p collisions at $\sqrt{s} = 200 \text{ GeV}$ with the Solenoidal Tracker at RHIC (STAR) (Fig. 1.). These data are 107.7 million minimum bias data collected with the coincidence requirement on the east and west Vertex Position Detectors VPD, the VPDMB data.

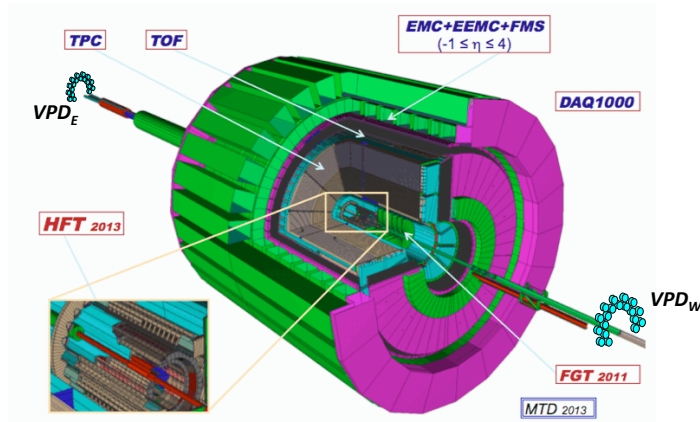


Fig. 1. The STAR detector. HFT and FGT are planned upgrades. TPC (Time Projection Chamber) is main detector for tracking and PID (provides $dE/dx, \mathbf{p}$), TOF (Time Of Flight) is used for PID improvement (time resolution 110 ps, start time is provided by VPD) and pileup tracks removal, BEMC (Barrel Electromagnetic Calorimeter) used for pile-up tracks removal and high p_\perp triggering.

The primary tracking device of the STAR detector is the Time Projection Chamber (TPC) [5]. Candidate tracks were selected having momenta $p(p_\perp) > 0.3(0.2) \text{ GeV}/c$ and pseudorapidity $|\eta| < 1$. TPC was used to reconstruct the D^0 decay with the help of newly installed Time of Flight Detector (TOF) [6]. TOF was used as a main PID tool to distinguish kaons from pions (up to $p_\perp = 1.6 \text{ GeV}/c$). Pions were identified via dE/dx provided by TPC as kaon contamination is small and requiring TOF PID for pions given limited TOF acceptance reduces the expected signal significance.

2.1. D^0 raw yield

From selected candidates, pairs were created and their invariant mass was reconstructed. The invariant mass spectrum of $K\pi$ pairs are presented in Fig. 2. The combinatorial background is reconstructed with three different methods:

- (i) **Mixed event:** Events are categorized according to the z-position of event vertices. Pions from one event are paired with kaons from other random events from an event pool with similar global features.

- (ii) **Track rotation:** Each π is paired with K with reversed 3-momenta (within same event).
- (iii) **Same Sign:** pions are paired with same charged kaons (within same event). The geometric mean for positive N_{++} and negative N_{--} pair is calculated as $2\sqrt{N_{++}N_{--}}$.

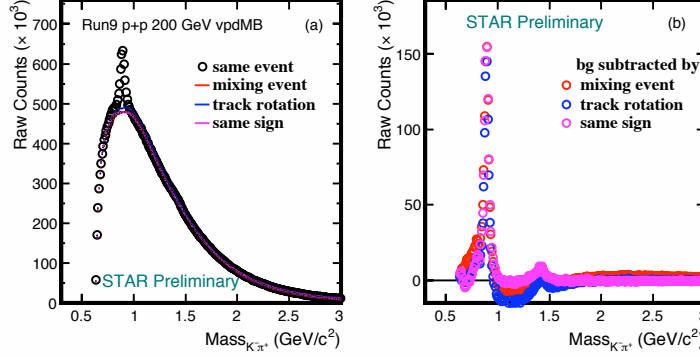


Fig. 2. (a) Invariant mass distributions of $K\pi$ pairs from p+p collisions with combinatorial background reconstructed with 3 different methods. (b) Invariant mass after combinatorial background subtraction

There are resonances $K^{*0}(892)$ and $K_2^*(1430)$ clearly visible in Fig. 2. To see a D^0 peak, the zoom to mass window from 1.72 to 2.1 GeV/c^2 is necessary, as seen in Fig. 3.

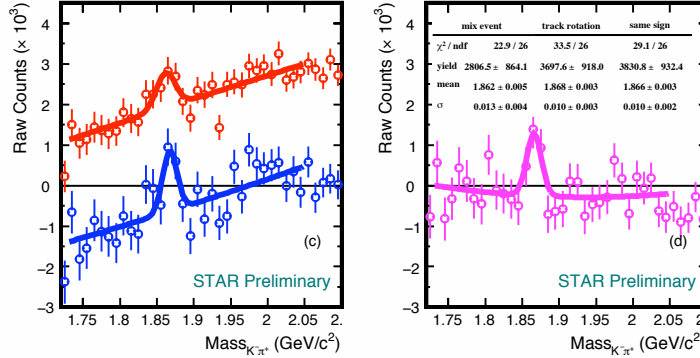


Fig. 3. (a) Invariant mass distributions of $K\pi$ pairs from p+p collisions after combinatorial background subtraction reconstructed through mixed event, track rotation (b) and same sign method.

As we see further from Fig. 3, mixed event method isn't able to fully reconstruct the whole background (only the combinatorial one). Same sign and track rotation reconstruct even non-combinatorial background sources additionally. From track rotation and same sign methods we obtain 4σ signal. The final results of open charm raw yield look quite consistent (within stat. errors) among these three methods, as seen in Table 1.

	mix. event	rotated \vec{p}	like sign
χ^2/ndf	22.9/26	33.5/26	29.1/26
raw yield	2806.5 ± 864.1	3697.6 ± 918.0	3830.8 ± 932.4
mean [GeV/c ²]	1.862 ± 0.005	1.868 ± 0.003	1.866 ± 0.003
resolution [GeV/c ²]	0.013 ± 0.004	0.010 ± 0.003	0.010 ± 0.002

Table 1: Parameters of D^0 raw yield (after comb. bg. subtraction) gaussian fit. The residual background is parametrized by second degree polynomial.

2.2. D^* raw yield

The D^* decay has a small Q -value. The D^0 thus carries most of the D^* momentum and the π from the D^* decay, denoted by π_s , is soft. The enhancement in the distribution of the invariant mass difference $\Delta M = M(K^\mp \pi^\pm \pi_s^\pm) - M(K^\mp \pi^\pm)$ is used to determine the D^* raw yield [7]. A mass interval $1.82 < M(K^\mp \pi^\pm) < 1.9 \text{ GeV}/c^2$ was used to select D^0 candidates and two methods were used for combinatorial background reconstruction, (see [8] for details). Combinatorial background was suppressed by requiring the $7 < p_\perp(D^0)/p_\perp(\pi_s) < 20$ and the decay angle of the K in the $K^\mp \pi^\pm$ rest frame, θ^* , to be restricted by requiring $\cos(\theta^*) < 0.8$ to remove near-collinear combinatorial background from jet fragmentation. The data sample used in the D^* reconstruction includes the minimum bias and the Jet-Patch triggered data. The triggered data requires the sum of transverse energies deposited in one patch of BEMC towers to be above a certain threshold. Result with all triggers is depicted in Fig. 4.

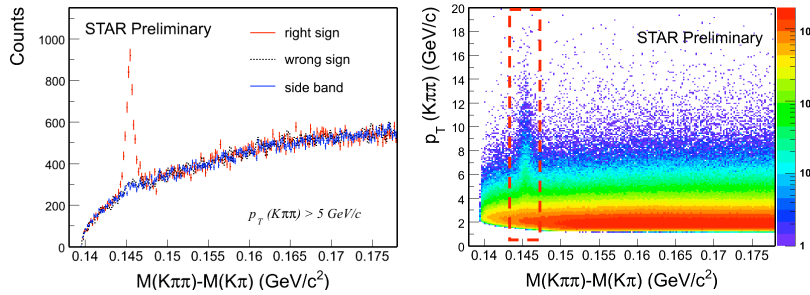


Fig. 4. (a) Invariant mass of $K\pi\pi - K\pi$ differences from p+p collisions with combinatorial background reconstructed through side band and wrong side techniques for high p_\perp D^* candidates (b) and scatter plot p_\perp vs inv. mass for all triggers.

3. Summary

Newly installed TOF detector improves particle identification in STAR significantly. The 4σ signal of D^0 meson in hadronic decays has been observed in p+p $\sqrt{s} = 200 \text{ GeV}$ collisions as well as strong D^* signal. Further efficiency and acceptance corrections are being carried out to extract the charm hadron spectra as well as the total charm cross section.¹

References

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